The ATLAS trigger system

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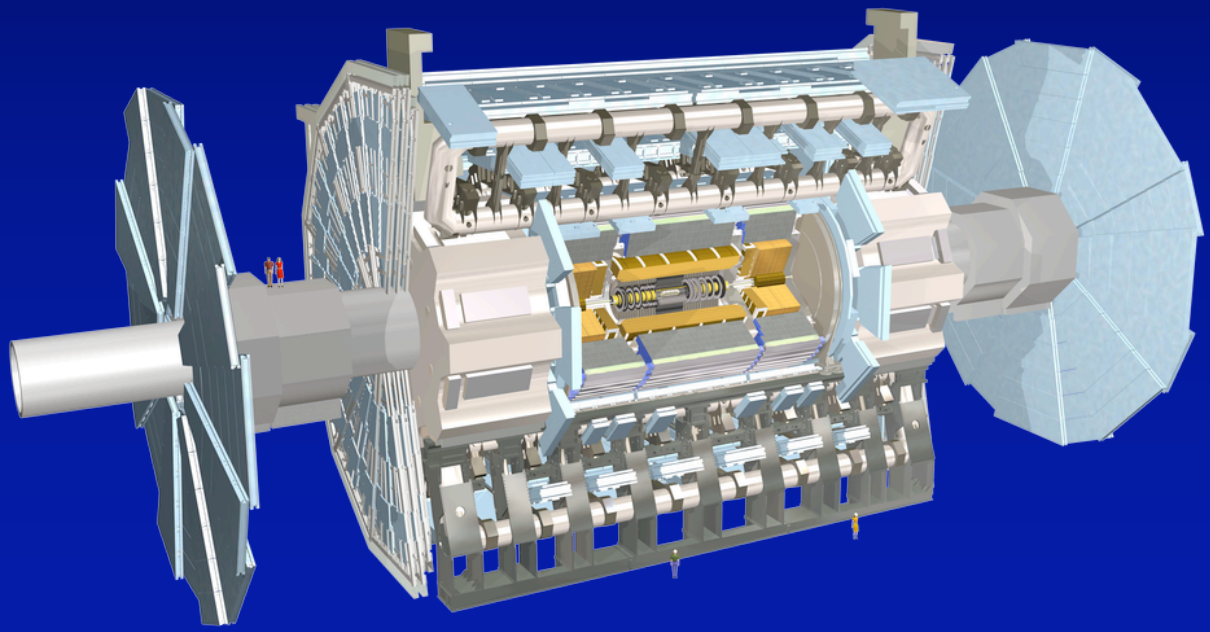
Four Seas Conference
Iasi, Romania

30 May 2007



Outline

- Introduction
- The ATLAS Trigger architecture and design
- The Level-1 trigger system description
- The High Level Trigger system description
- Integration and Commissioning results
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Introduction

- LHC is a proton-proton collider at CERN.
- ATLAS/CMS are multi-purpose experiments.
- Taking into account:
  - Cross-section at $\sqrt{s}$ = 14 TeV:
    σ_{tot} (p-p) ~ 0.1 b = 10^{-25}cm^2
  - L = 10 000 x 10^{30} cm^{-2}s^{-1}

Total event rate ~ 10^9 Hz (1 ev each ns)

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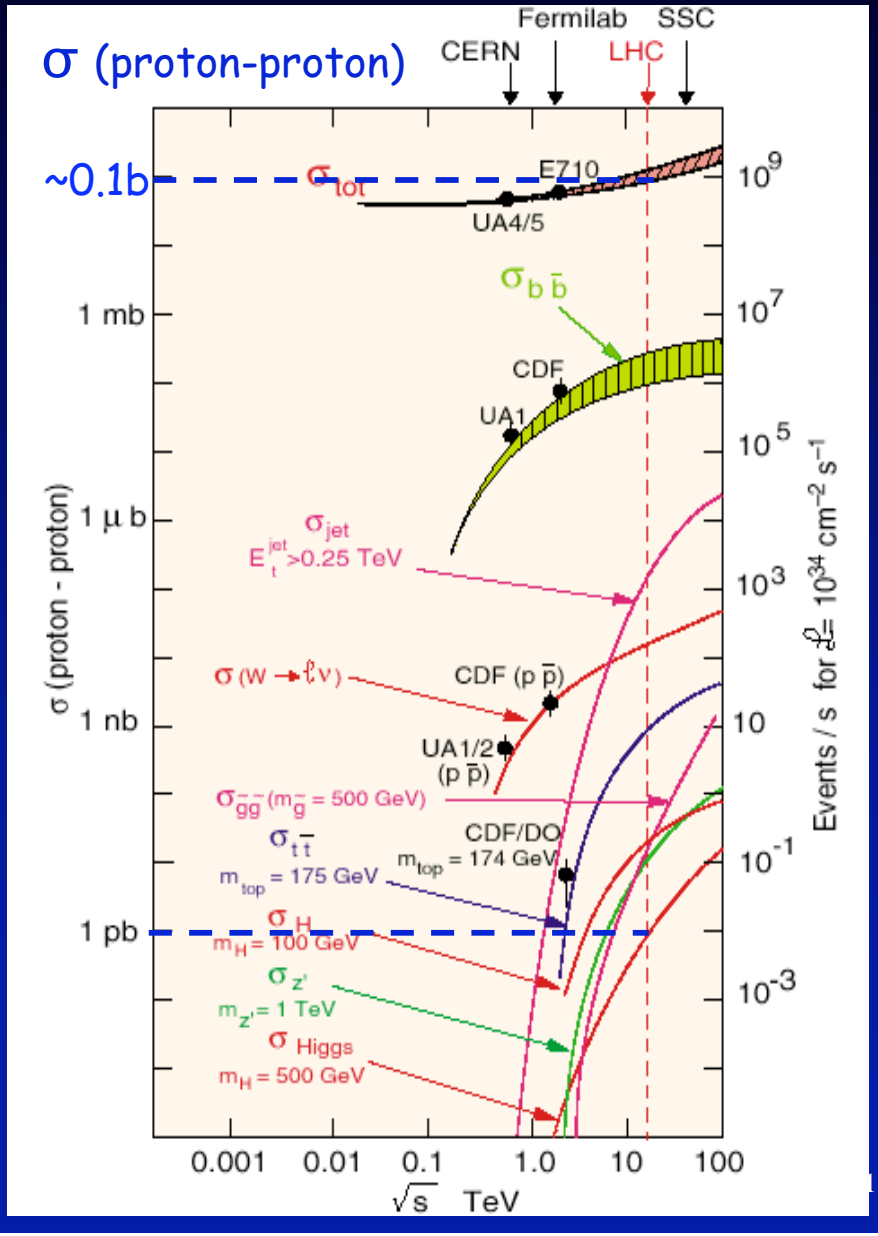
- The detector is filled most of the time with uninteresting physics.
- Interesting events like Higgs have $\sigma_{H\ (m=500GeV)}$ ~ 1 pb = 10^{-36}cm^2

Higgs event rate ~ 0.01 Hz



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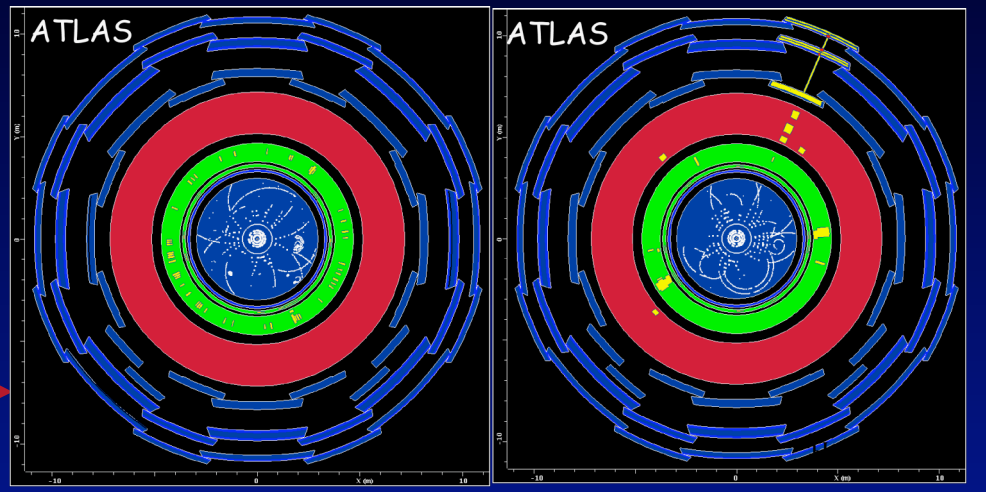

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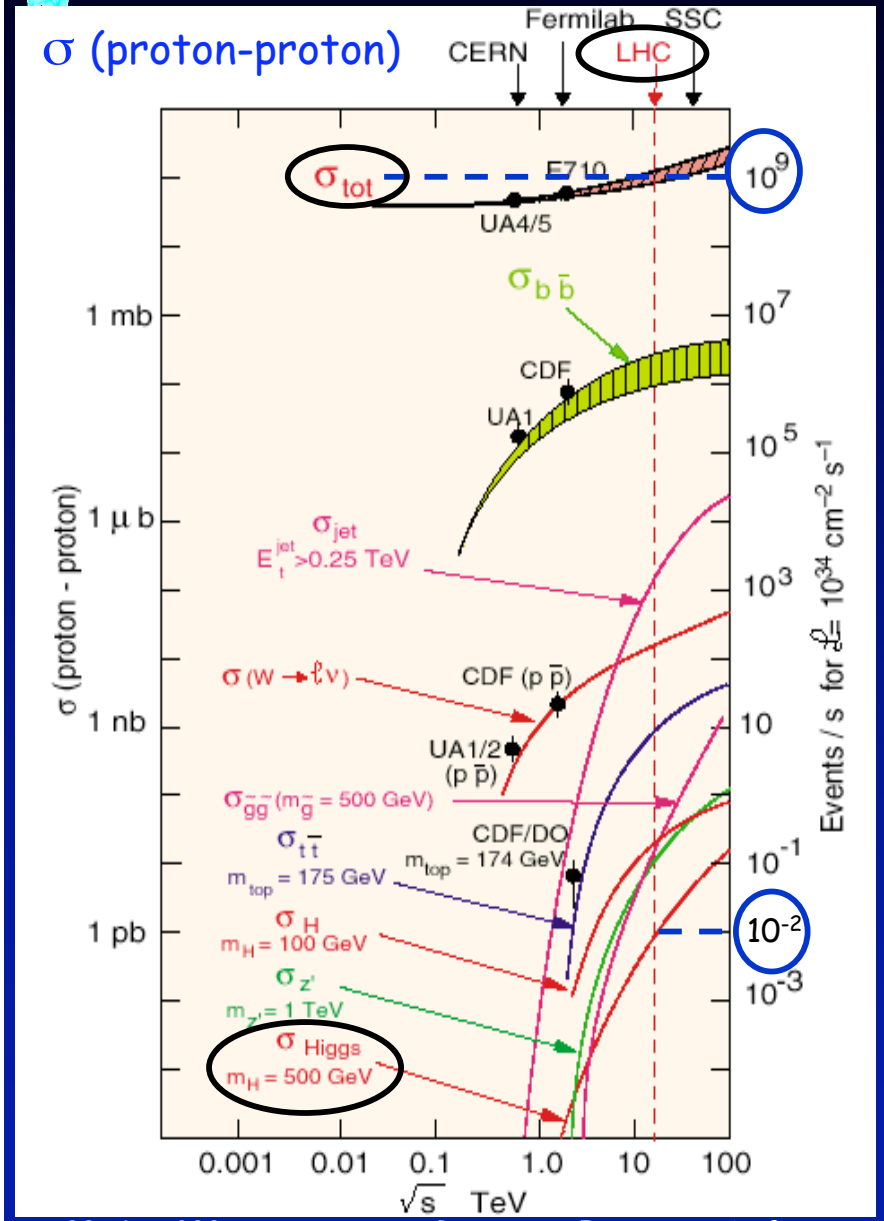
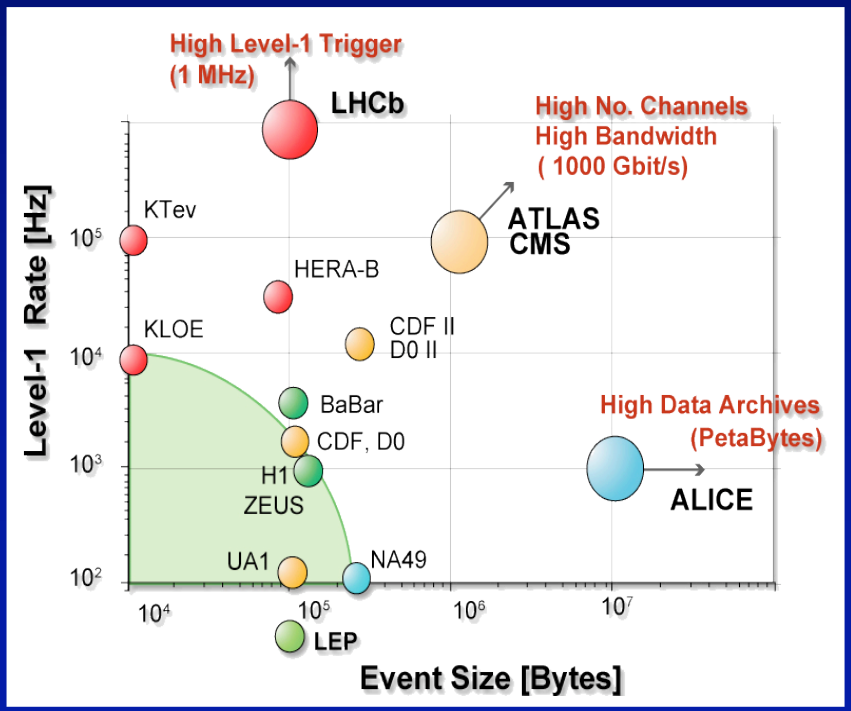
10^{12} reduction power for Higgs search: Challenging!

A trigger system is needed to identify among all events, the interesting ones.

Difficult task of the ATLAS trigger



- Rejection power for Higgs search 10^{12}
- # overlapping events / 25 ns 23
- # particles in ATLAS / 25 ns 1400
- Data throughput
  - At detectors (40 MHz) (equivalent to) PB/s
  - → LVL1 Accepts 120 GB/s
  - → Mass storage ~300 MB/s



ATLAS Inclusive Selection Signatures

- ATLAS is a multipurpose experiment aiming at discovery and precision measurements of "expected" and "unexpected" Physics signals.
- The selection of Physics signals requires the identification of objects that can be isolated from the high particle density environment.

Object	Examples of physics coverage	Nomenclature
Electrons	Higgs (SM, MSSM), new gauge bosons, extra dimensions, SUSY, W, top	**e25i, 2e15i**
Photons	Higgs (SM, MSSM), extra dimensions, SUSY	**g60i, 2g20i**
Muons	Higgs (SM, MSSM), new gauge bosons, extra dimensions, SUSY, W, top	**m20i, 2m10**
Jets	SUSY, compositeness, resonances	**j360, 3j150, 4j100**
Jet+missing E_T	SUSY, leptoquarks	**j60 + xE60**
Tau+missing E_T	Extended Higgs models (e.g. MSSM), SUSY	**t30 + xE40**

The list must be flexible, extendable, non-biasing and general enough to account for the "unexpected".

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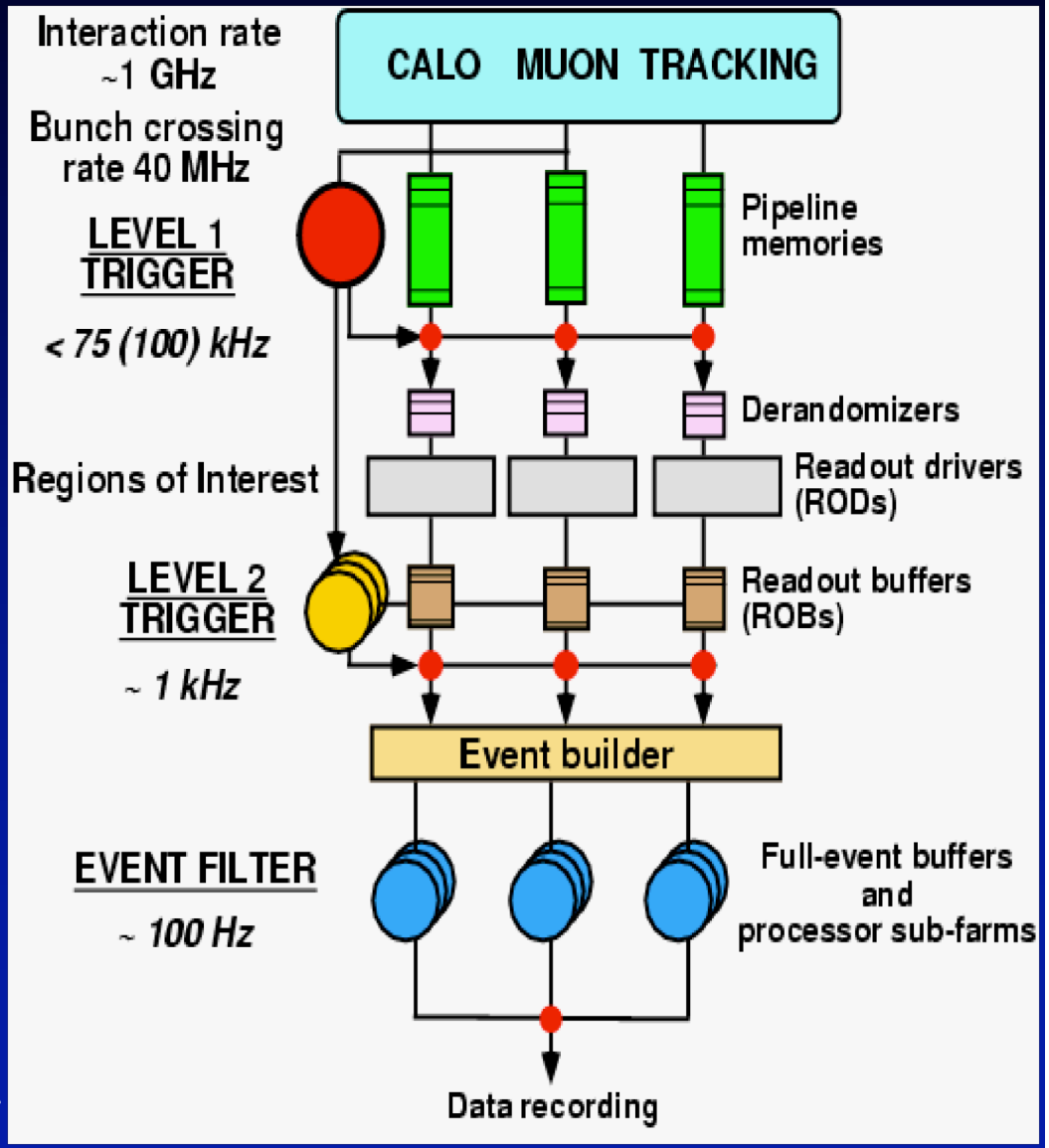
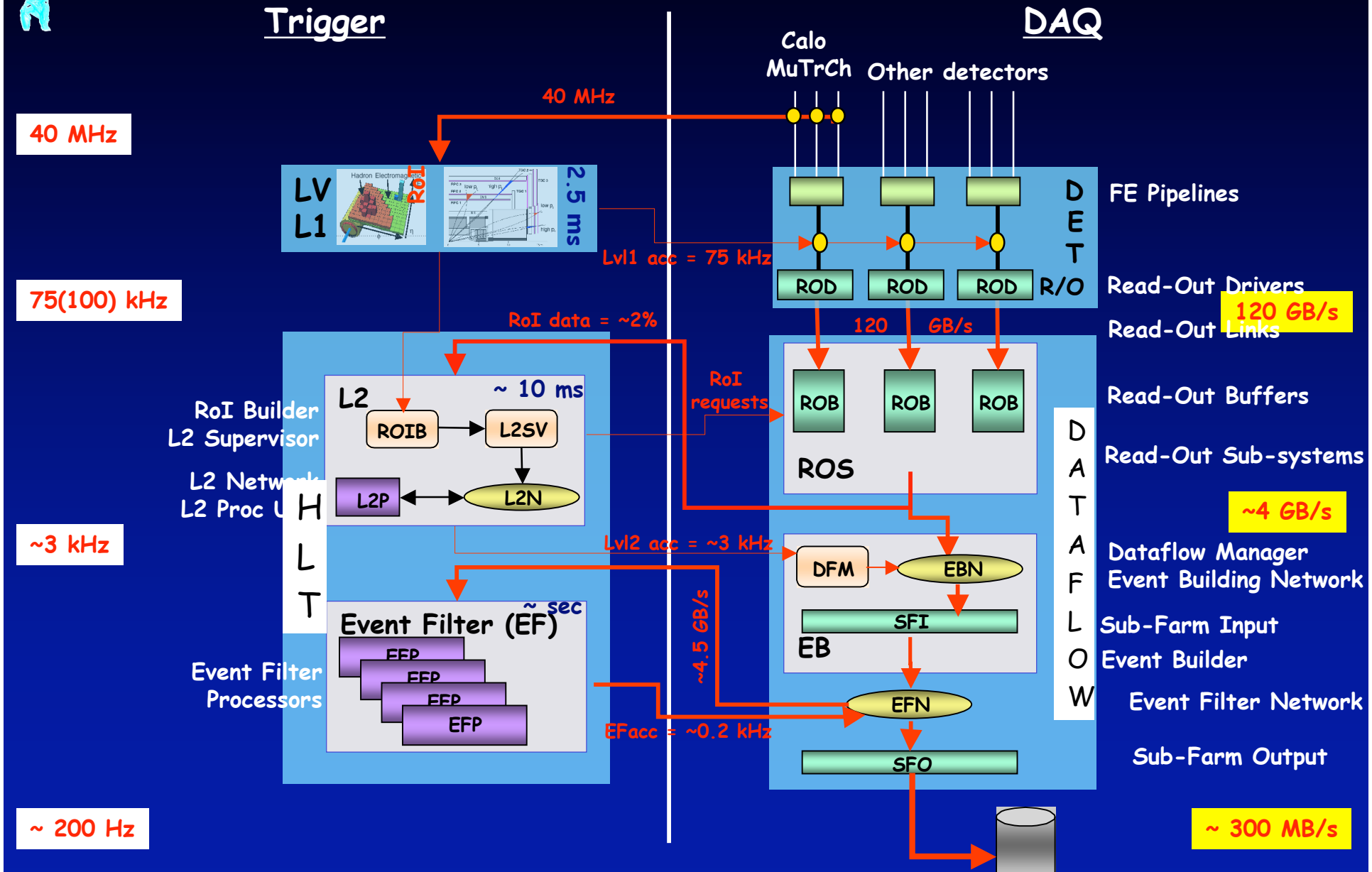
ATLAS trigger system: design

- Level 1
  - Hardware based
    - 2.5μs max latency
    - Calorimeter/Muon system
- Level 2
  - PC farm, Software based
    - 10ms mean processing time
    - Specialized algorithms
    - Access to full granularity data within a Region of Interest (RoI)
- Event Filter
  - PC farm, Software based
    - 1s mean processing time
    - Adapted offline reconstruction algorithms
    - Access to full event
    - Algorithms are/can be seeded by LVL2 result
    - Access to complete calibration & alignment data

H L T



ATLAS Trigger/DAQ system: architecture



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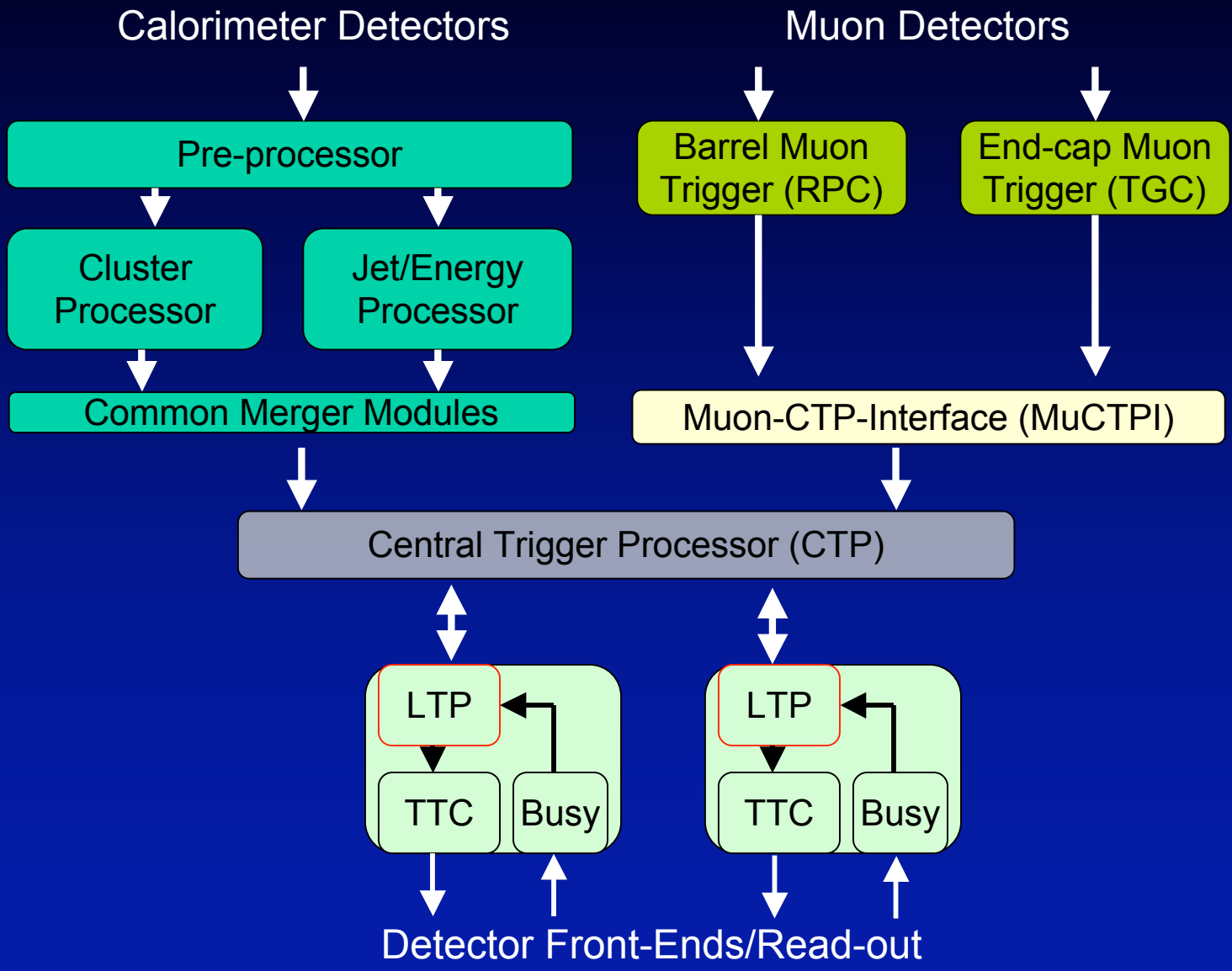
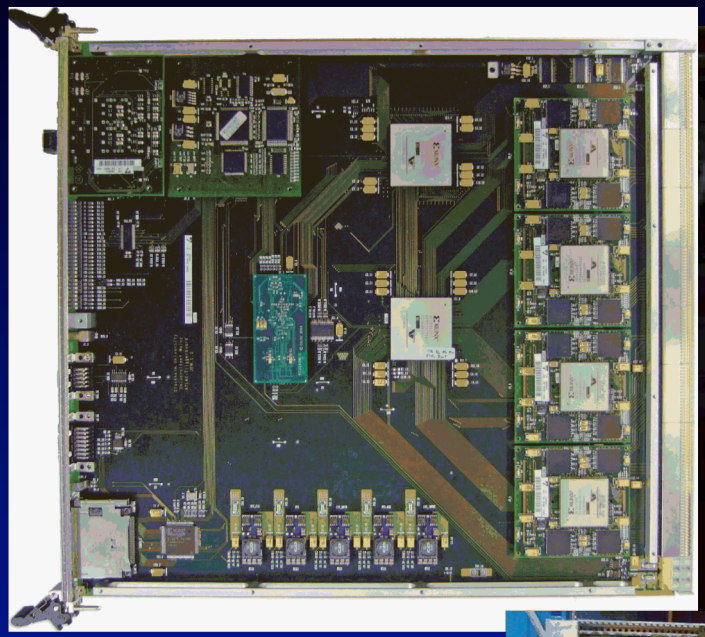
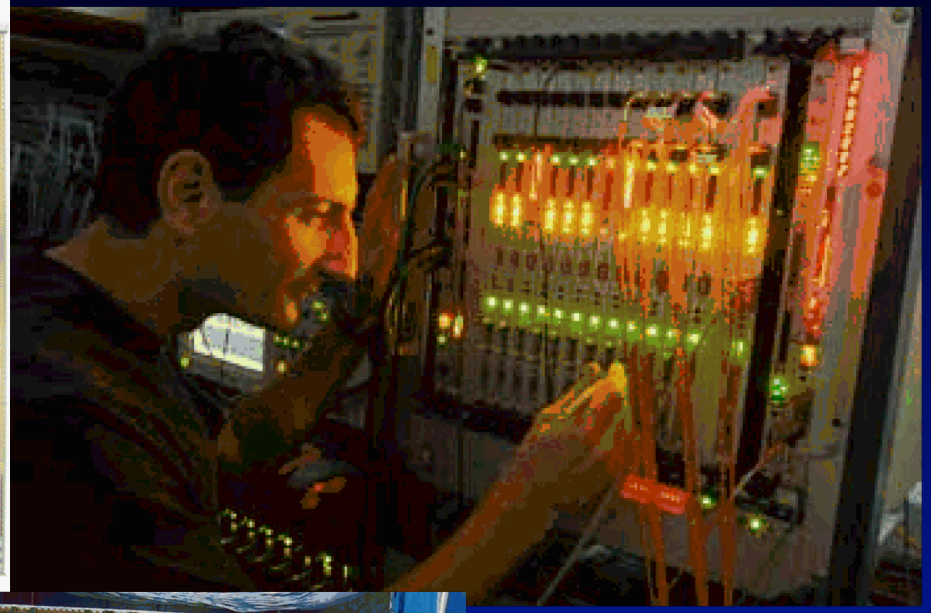
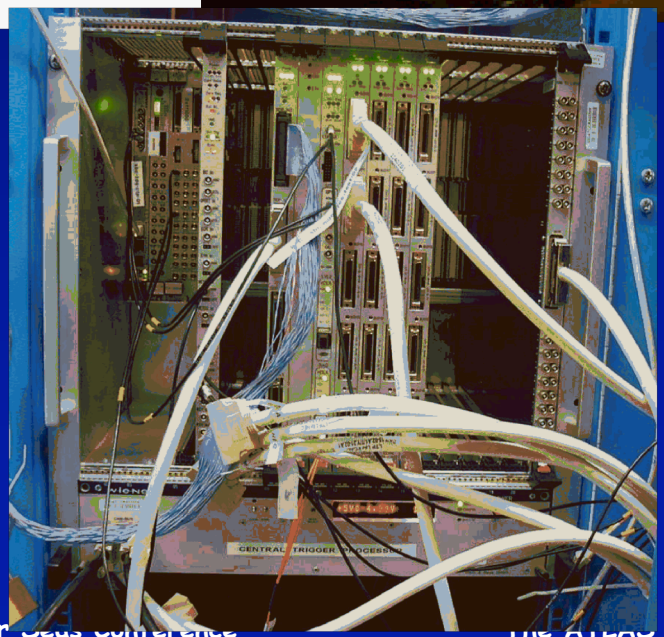
ATLAS Level-1 trigger



ATLAS Level-1 trigger







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The ATLAS HLT design concept

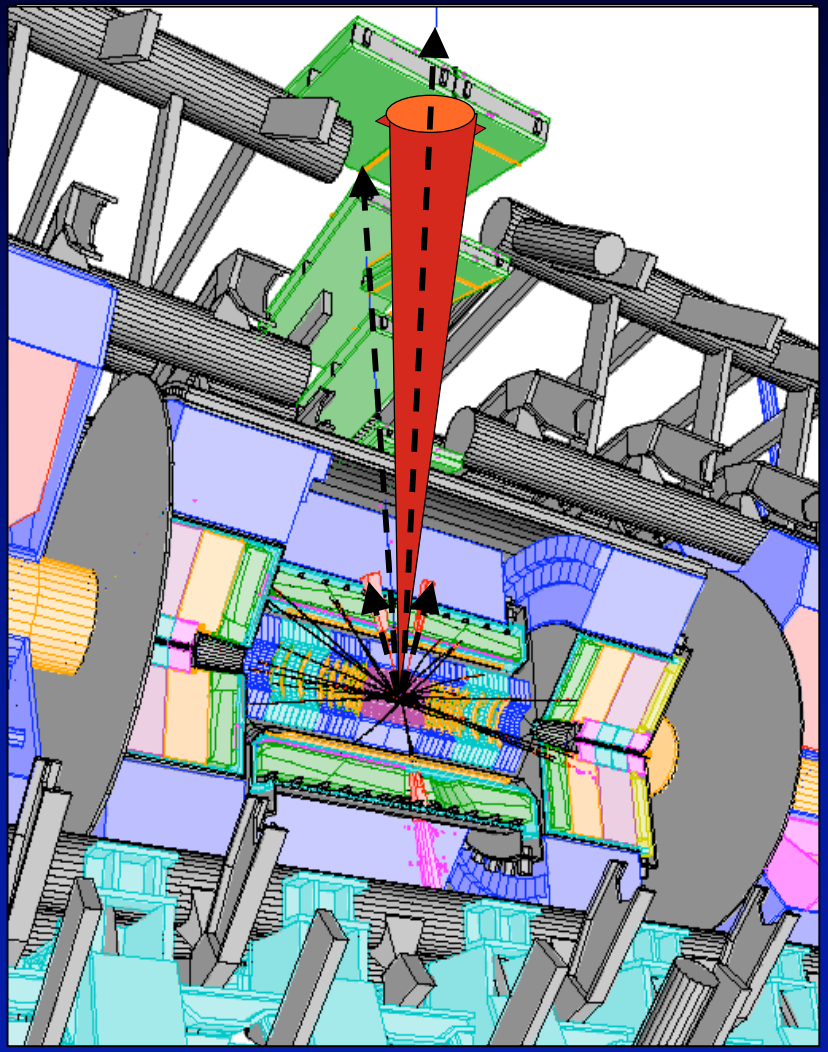
- Main ideas in the design of the ATLAS High Level Trigger:
  - RoI-based → requests and process as little data as possible
  - Step-wise → rejects events as soon as possible
    - Minimizes CPU and network bandwidth but..
    - Adds complexity → need special algorithm scheduling, not just sequential

- ATLAS decided to "re-use" some elements of the offline framework inside the HLT:
  - Pros:
    - Converters from detector readout to algorithms input are provided by detector experts
    - Ease development of HLT algorithms and performance studies
  - Cons:
    - Increase of software dependencies: HLT is offline release dependent
    - Need to obey more severe constraints like timing and robustness

ATLAS Level-2: Region of interest based

- Level-1 identifies Regions of Interest (RoI) and are defined by (η,ϕ).
- The average number of ROIs per event is ~1.6
- Level-1 ROIs are used at Level-2 and a refined selection performed only using data along the ROI path (represents ~2% of full detector)

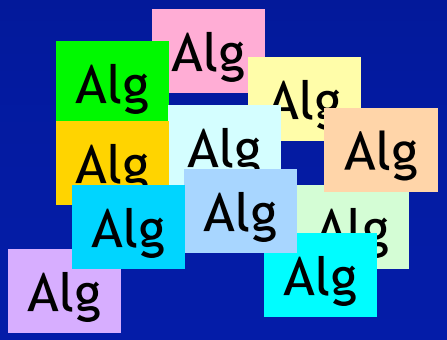
$H \rightarrow ZZ' \rightarrow e^+e^-\mu^+\mu^-$ in ATLAS



How does the HLT work?

Sequential call of algorithms

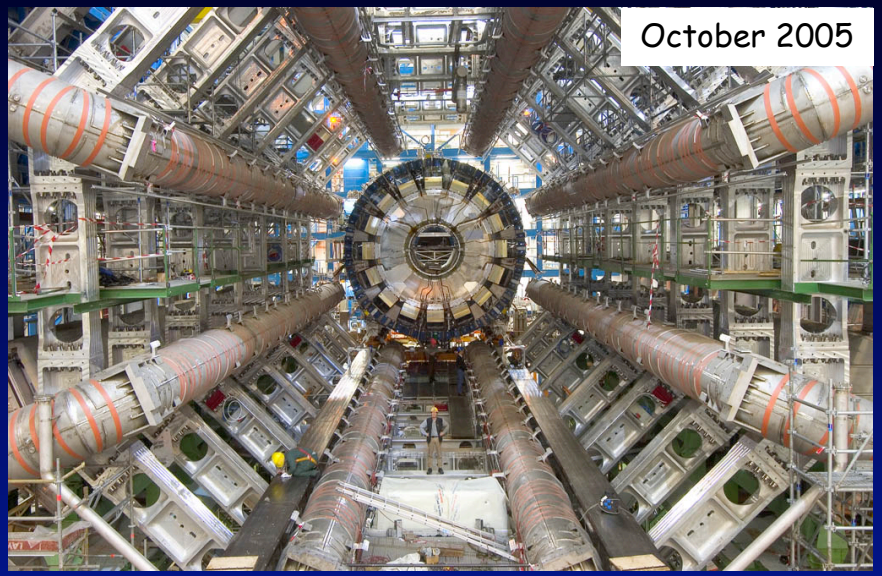
- Two isolated electromagnetic clusters with pt>20GeV are found by LVL1:
  possible signature for $Z \rightarrow e^+e^-$
- Goal: Validate step-by-step, check intermediate signatures, reject at earliest possible moment

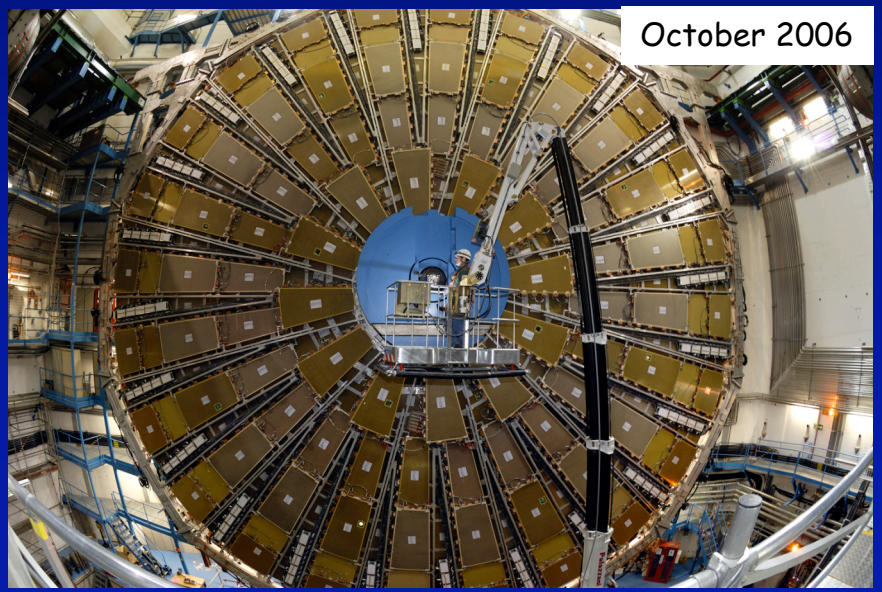


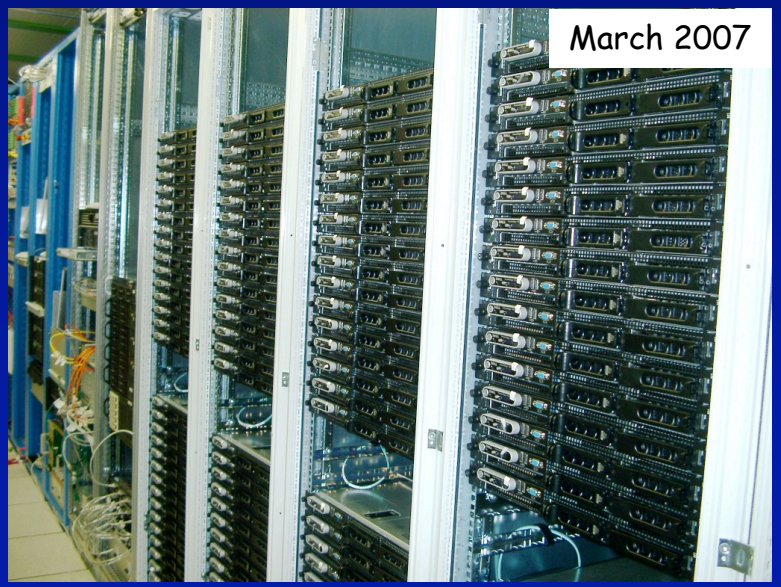
Signature →	e30i	+	e30i
STEP 4	Iso lation		Iso lation
Signature →	e30	+	e30
STEP 3	pt> 30GeV		pt> 30GeV
Signature →	e	+	e
STEP 2	track finding		track finding
Signature →	ecand	+	ecand
STEP 1	Cluster shape		Cluster shape
Level1 seed →	EM20i	+	EM20i

time

Parallel installation of ATLAS and TDAQ







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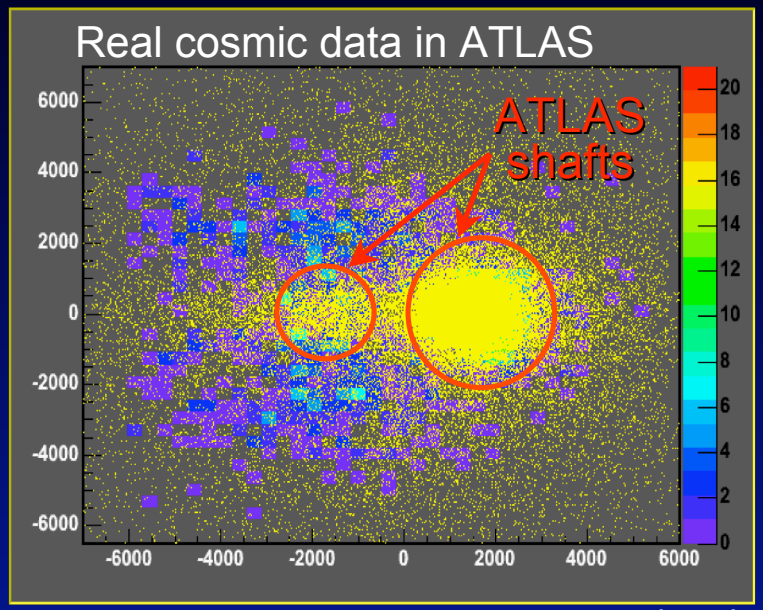
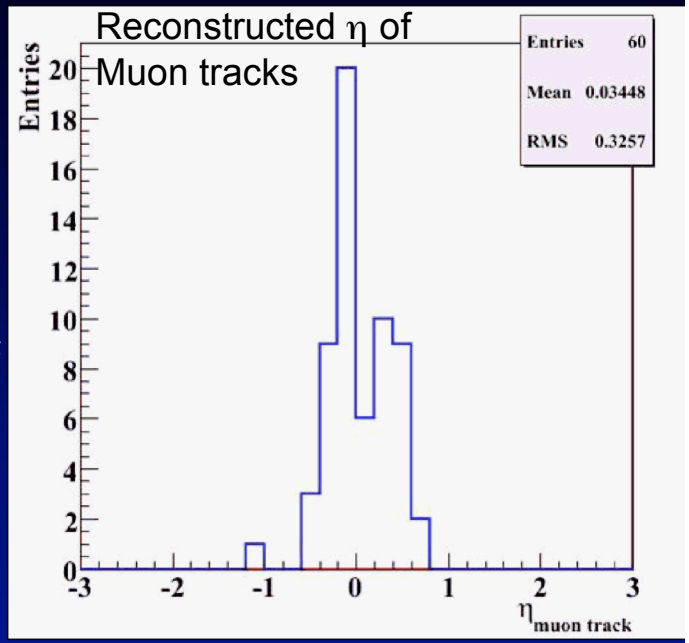
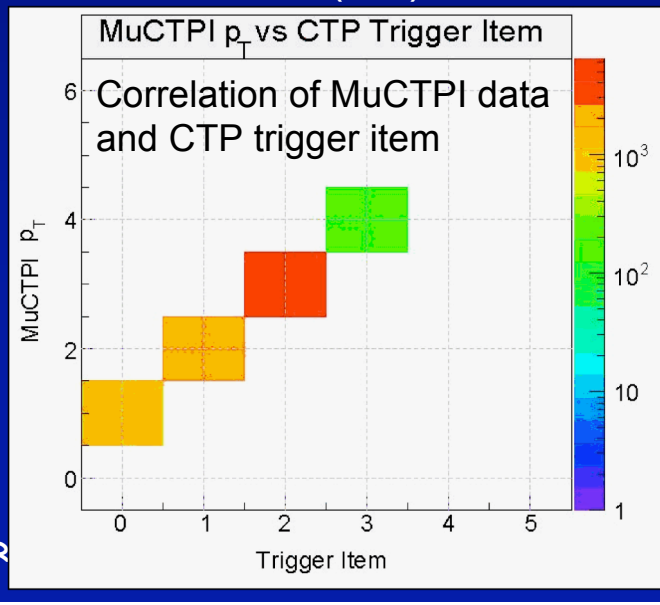
Commissioning of the trigger with cosmics

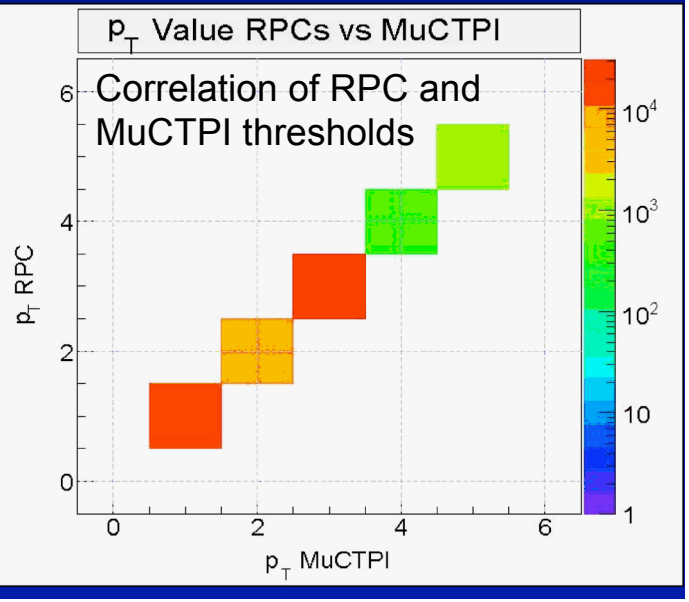


LVL1 and LVL2 integration tests include running LVL2 algorithms reconstructing η of downgoing cosmic muons using LVL1 ROIs online



Important consistency checks within LVL1 muon and CTP and between LVL1 boards and muon detector



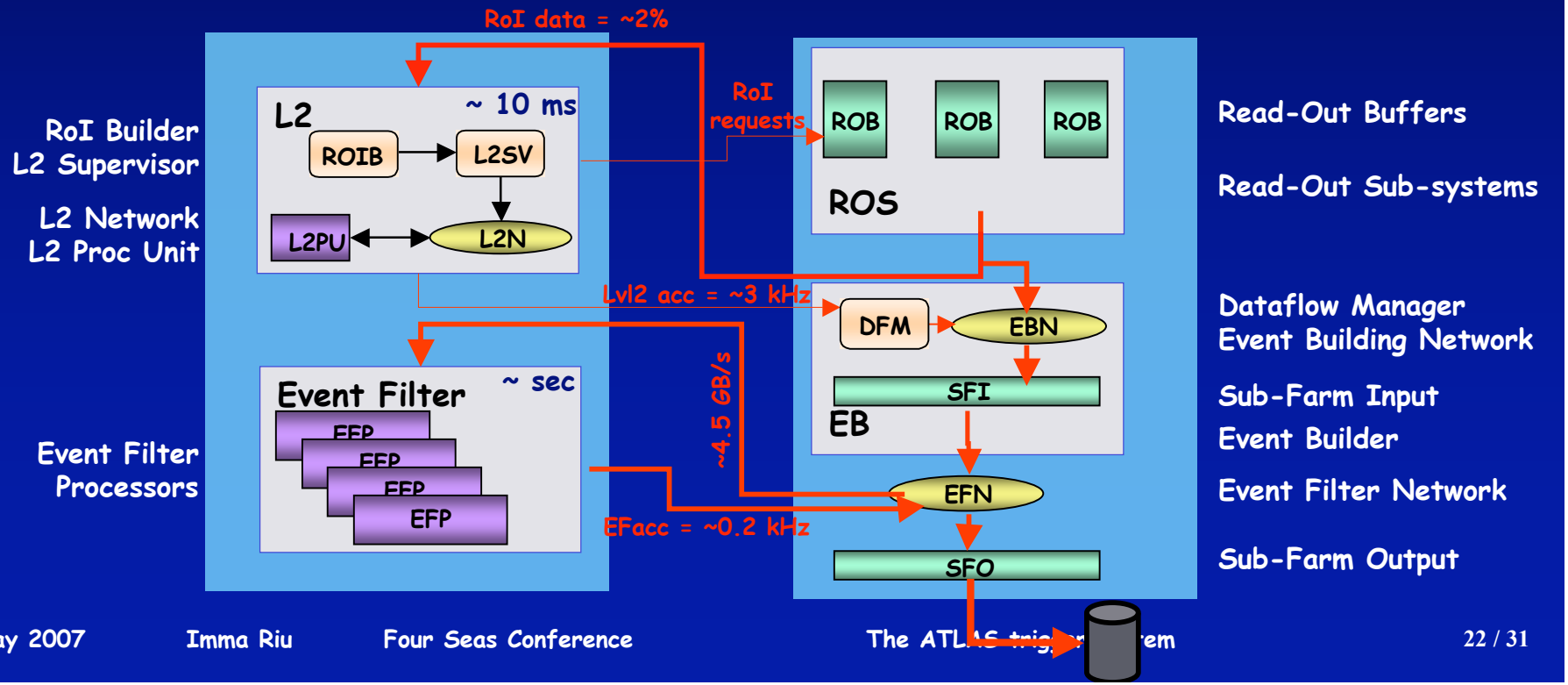


Integration and commissioning of HLT

HLT	Pre-series test system	Final system
L2SV	2	12
L2PU	12	~500
EFP	30	~1900

Dataflow	Pre-series test system	Final system
ROS	12	~150
DFM	2	12
SFI	6	~100
SFO	2	~5
Online	2	20
Monitoring	4	32
File Servers (FS)	5	~80

A total of ~80 PCs have been used



Test system hardware description

A total of 8 racks representing ~10% of the final ATLAS dataflow system have been used

ROS rack

12 ROS PCs
1 FS PC

RoIB rack

VME crate
50% of RoIB

L2 rack

12 L2PU PCs
1 FS PC

Supervisor rack

2 L2SV PCs

Switch rack

128-port GEth for L2+EB

Dataflow rack

2 DFM PCs
6 SFI PCs
2 SFO PCs
1 FS PC

EF rack

30 EFP PC
1 FS PC

ONLINE rack

4 monitor PC
2 online PC
1 FS PC

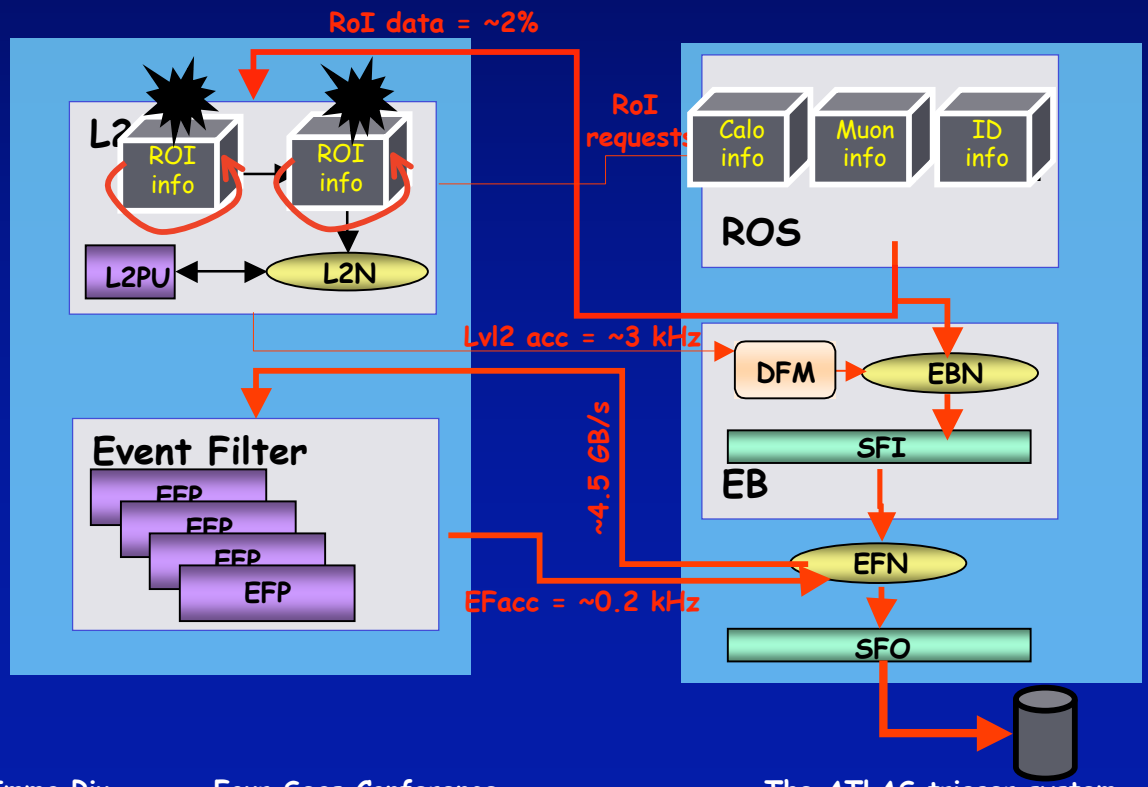
underground

surface

The PCs are single core machines Intel Xeon 3.2 GHz or AMD Opteron 2.4 GHz

Integration tests description

- Monte Carlo simulated data with LVL1 information are written in raw data format
- LVL1 ROI information is loaded into the ROIB and detector information into the ROS
- The trigger is done in the ROIB crate itself
  - A second possibility is to use the L2SV for loading the LVL1 ROI information and triggering

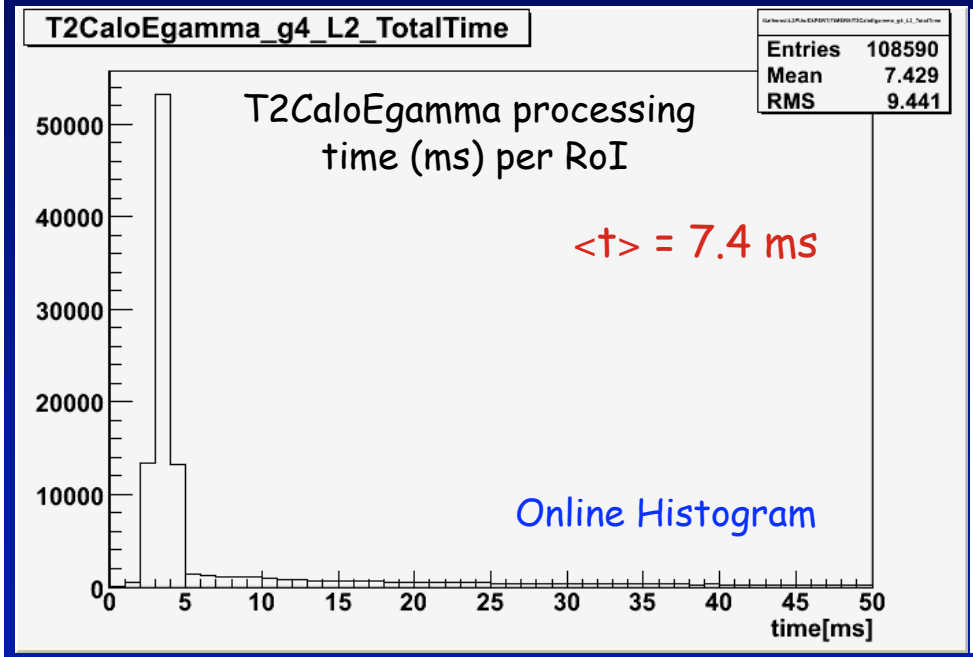


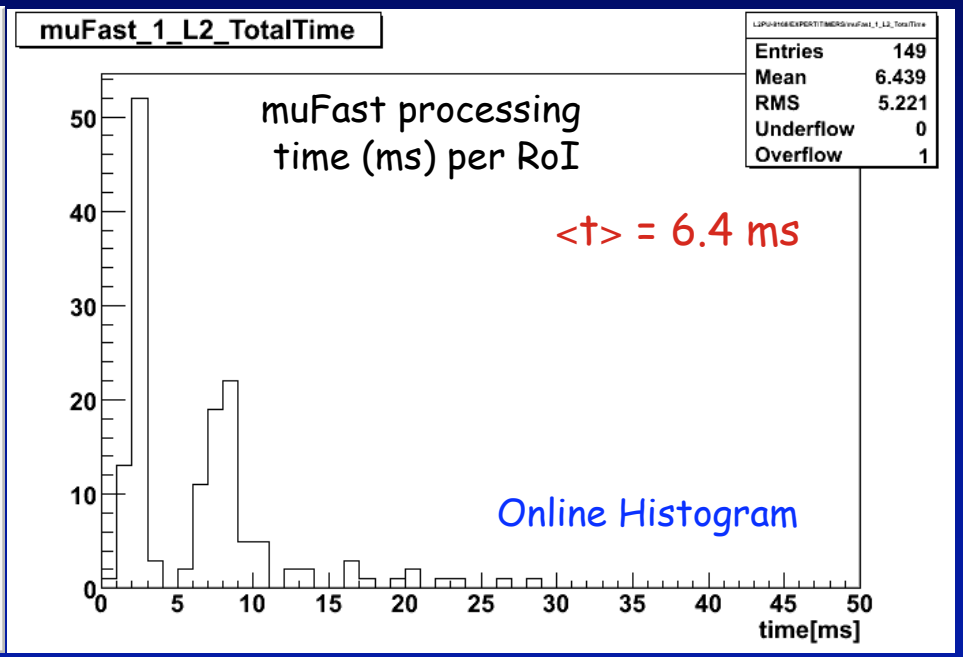
Organization tests description

- Runs take place every around two months involving all experts
- Organized as in a data taking period:
  - Organized in three shifts during day time
  - Each shift involves two teams:
    - Data acquisition team
    - Monitoring team

Integration test results: L2 time measurements

- Processing time of different algorithms per RoI:
  - T2CaloEgamma:
    - L2 algorithm that finds clusters in the ATLAS calorimeters
  - muFast:
    - L2 algorithm that finds muon tracks using the ATLAS muon spectrometer



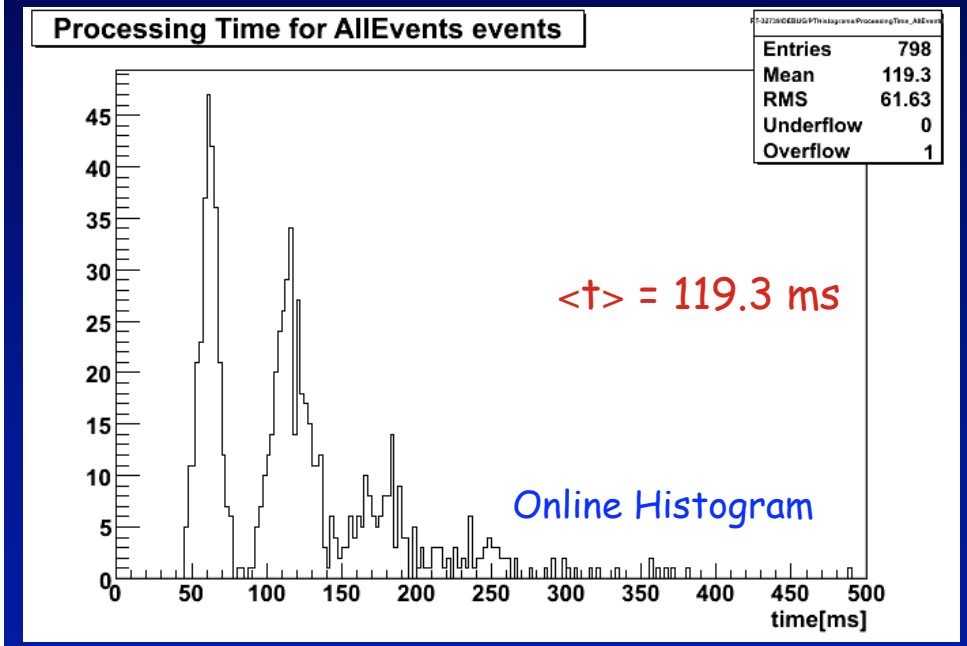


Average time per RoI within the ATLAS L2 time budget

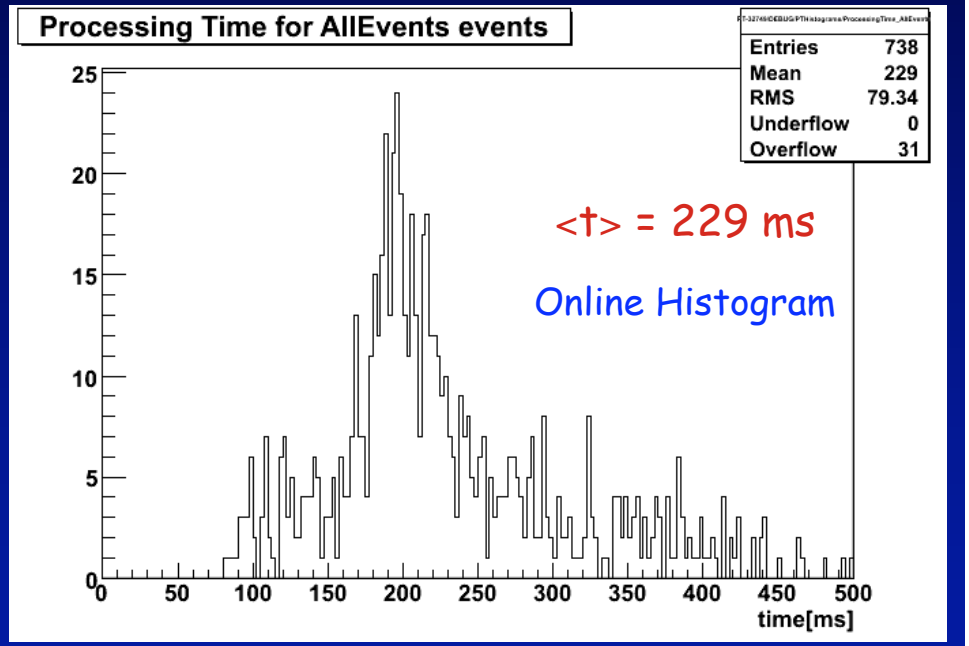
Integration test results: EF time measurements

Total processing time of different algorithms per event

Event processing time running EF jet algorithms



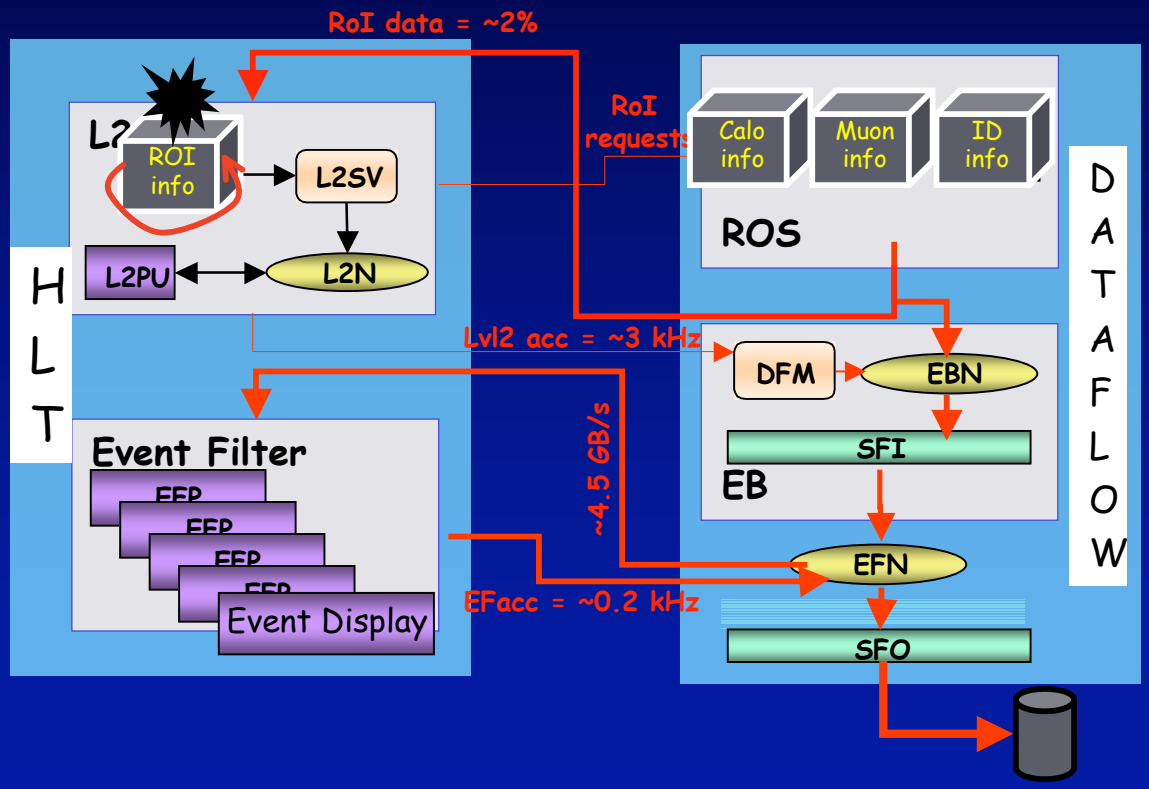
Event processing time running EF tau algorithms



Average time per event within the ATLAS EF time budget of ~1s

Integration test results: event display

- The ATLAS event display has been integrated and is automatically running when integration and commissioning tests are going on



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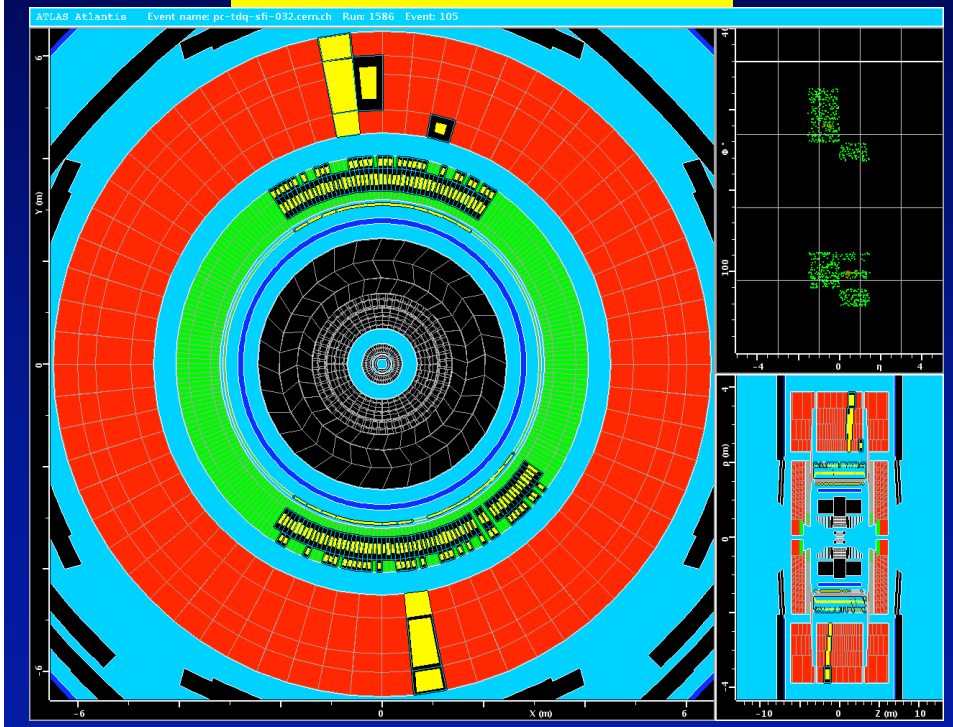
Cosmic event in ATLAS



Run meeting in the ATLAS control room

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Conclusions and outlook

- The ATLAS Trigger and DAQ systems are being installed in ATLAS
- Level-1 and HLT integration tests involving a system of around 80 computers have taken place several times since mid 2006
- Level-1 muon trigger has been shown to produce consistent results with real cosmics
- HLT algorithms timing have been shown to be within the allocated time budget
- The ATLAS commissioning with cosmic events will continue during 2007 and the trigger tested and commissioned
- Looking forward to the ATLAS data taking period!

Backup slides

Dataflow for the HLT